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STATUS OF ADONE AS SYNCHROTRON RADIATION SOURCE

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Status of Adone as Synchrotron Radiation Source

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Introduction

The first application of synchrotron radiation (SR) at Frascati started in 1965 with a collaboration between the University of Rome and the Istituto Superiore di Sanità, which exploited the light coming from the electron-synchrotron for absorption and reflectivity measurements in the X-VUV region.

Ten years later a project for the utilization of Synchrotron Light (PULS) was set up and the convention establishing the PULS collaboration was signed by the National Research Council (CNR) and the National Institute for Nuclear Physics (INFN). From 1975 to 1980 an experimental facility was built around the photon beam line originating from a bending magnet of the storage ring ADONE.

In 1975 the construction of a wiggler magnet for both machine physics studies and production of hard X rays was decided by the INFN. The wiggler was installed in 1978 on a straight section of ADONE and the compatibility with the normal operation of ADONE was demonstrated successfully. Also a laboratory for the utilization of synchrotron light from this magnet (PWA) was built by INFN and inaugurated in May 1985.

The PWA and PULS laboratories joined together in 1983 with the new convention between INFN and CNR for the utilization of synchrotron radiation and development of its application.

The experiments, that have been carried out by scientists of INFN, CNR, the Universities and other Institutes, both italian and foreign (mainly from France, Poland, U.K., USA) are about 160, while the present experimental proposals are over 80.

These are submitted for approval to a Scientific Committee (4 members of INFN, 4 members of CNR) on the basis of recommendations of international referees.

The proposals concern all traditional areas of research in Physics, Chemistry, Biology, Surface and Material Science. The facility budget for 1985, including the capital and operating costs is about 0.5 M$.

In the following we shall report on the present status of the storage ring ADONE and describe the main features of the SR facility.

The Machine

The storage ring ADONE[1] came into operation in 1969 and since then provided a lot of scientific results not only in the field of e^+e^- physics, but in others important research areas too, such as nuclear physics, SR, etc. Fig. 1 shows a layout of the ring with the main research activities. It is a strong focusing, separated function machine, with 12 equally long straight sections; the injector is a S-band Linac, which is also used for nuclear physics experiments. The main parameters of the Linac and ADONE are listed in Table I.

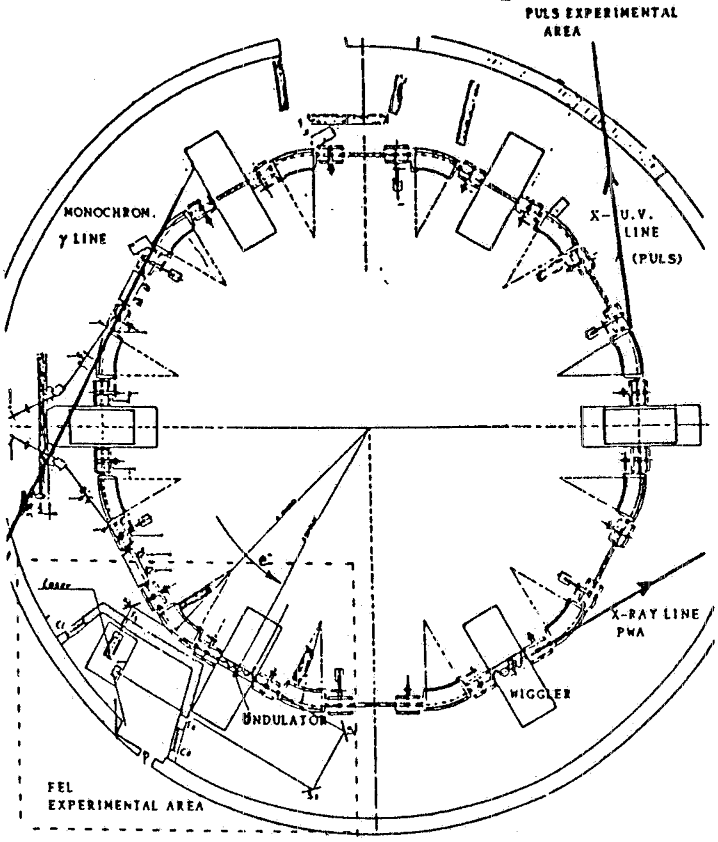

Fig. 1 - Layout of the storage ring ADONE.

Table I

Injector		ADONE	
Type	S-Band Linac	Energy	1.5 GeV
Maximum energy	380 MeV	Beam current	100 mA
Injector current e^-	100 mA	Circumference	105 m
Injector current e^+	1 mA	Revolution period	350 nsec
Injection energy	300 MeV	Bending radius	5 m
Max. repetition rate	250 pps	Bending field	1 Tesla
Injection rep. rate	1 pps	Field index	0.5
Pulse length	4 μsec	RF frequency	51.4 MHz
		Harmonic number	18
		RF peak voltage	300 kV

At present, 3 major research lines are implemented on ADONE:

1) The SR physics with a bending magnet beam line (PULS) and a wiggler beam line (PWA).
2) The nuclear physics with low energy monochromatic γ-rays, produced by head-on collisions of a CO_2 laser beam with the electron beam (LADON).
3) The Free Electron Laser (FEL) experiment, which makes use of an undulator magnet installed on ADONE (LELA).

Also, we should mention the experimental programme for the measurement of the neutron form factor (FENICE), which will bring ADONE back to e^+e^- operation after 10 years.

The ADONE optical structure is a simple $\frac{0}{2}$ FDBDF $\frac{0}{2}$ lattice, whose basic parameters are given in Table II(a). The betatron wave functions and the off-

Table II - Lattice Parameters for the standard (a) and the zero-dispersion (b) optics.

	(a)	(b)
Number of periods	12	6
Period length (m)	8.75	17.5
Horiz. betatron tune	3.15	5.15
Vert. betatron tune	3.15	3.15
Momentum compaction	6.2×10^{-2}	1.36×10^{-2}
Relative energy spread	0.58×10^{-3}	0.56×10^{-3}
Natural emittance (m·rad)	2.2×10^{-7}	2.4×10^{-7}
Horiz. chromaticity	- 3.28	- 5.5
Vert. chromaticity	- 3.16	- 4.7

energy function are shown in Fig. 2. To meet the experimental requirements of the LELA experiment, a new lattice has been proposed[2], which increases the number of independent quadrupoles families from 2 to 4. The periodicity is changed from 12 to 6 and the off-energy function vanishes in alternate straight sections, thereby allowing optimum values for the beam size and divergence and energy spread. The parameters of this new optics are listed in Table II(b) and the resulting optical functions are shown in Fig. 3.

Since the undulator is dedicated to the Free Electron Laser experiment, we shall not describe its characteristics here, which are to be found in ref. (3).

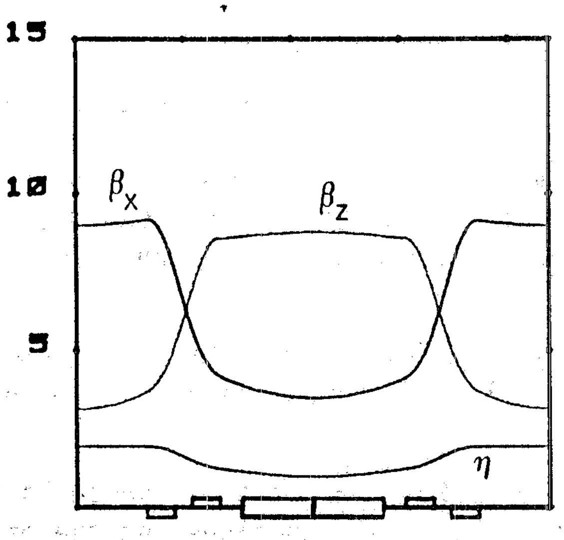

Fig. 2 - Standard lattice: a full period.

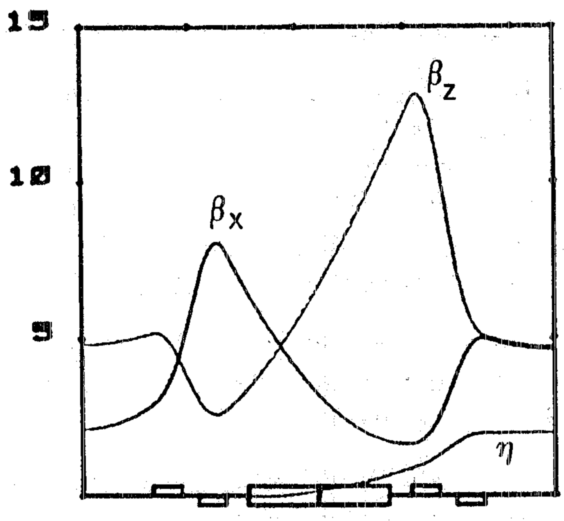

Fig. 3 - Zero-dispersion lattice: half a period.

The Synchrotron Radiation Sources

The basic parameters concerning the SR source from the bending magnet are given in Table III. All values refer to the maximum energy of 1.5 GeV.

Beam sizes and divergences are given as one standard deviation of gaussian distribution at the beginning of the bending magnet with a 4% emittance coupling.

The normal operation current is 100 mA, and up to 18 bunches can be independently filled.

Table III - Synchrotron Radiation Parameters.

Energy loss/turn (keV)	90	
Critical energy (keV)	1.51	
Electron beam sizes (mm)	σ_x = 1.06	σ_z = 0.27
Electron beam divergences (mrad)	σ'_x = 0.25	σ'_z = 0.03
Brilliance at crit. energy (photons/s eV (cm·mrad)^2	1.6×10^{14}	
R.m.s. bunch length (cm)	12	
Number of bunches	1 to 18	
Beam lifetime (hours)	4	

The intrinsic angular spread of the emitted radiation is about 0.34 mrad at 1.5 GeV, and dominates on the beam angular spread in the vertical plane.

A beam lifetime of about 4 hours at 1.5 GeV is achieved after a prolonged beam conditioning.

The main characteristics of the wiggler magnet are listed in Table IV. For further details se ref.(4).

Table IV - Wiggler characteristics.

Magnet period	654 mm
Number of poles	5 full - 2 half
Total length	21 m
Gap height	40 mm
Max. field on axis	1.85 T
Excitation turns per pole	7
Copper weight	270 kg
Current	4500 A
Current density	18 A/mm^2
Total power	230 kW
Total radiated power	13 W/mA

The fundamental design elements can be regarded as a sort of compromise between the requirement of a hard X-ray source for SR and the need to gain experience on the storage ring operation.

The wiggler experimental facility consists of two beam lines, BX_1 and BX_2, which will be used for studies of biophysics and diffractometry, besides the usual absorption and fluorescence experiments.

A comparison of the existing X-rays lines is summarized in Table V. Fig. 4 shows the total flux from the bending and the wiggler magnet. The dashed line is the flux as transmitted by a Be window that is located 12 m away from the wiggler. Also, the flux from a superconducting wiggler under design at Frascati is shown. This device is expected to be operating on ADONE by the end of 1987 and will consist of a single pole with two unexcited screens and 2 compensating magnets. Max. field will be 6 Tesla to achieve a critical energy of 9 keV. Computer simulation has shown that this configuration would minimize the perturbations of the machine optical functions and optimize the SR source for experiments.

Table V - X-ray lines parameters.

Source	Bending magnet	Wiggler magnet (BW = 1.85 T)
Number of light pipes	1	BX_1 (BX_2)
Energy range	(2-12) keV	(3-30) keV
Critical energy ε_c	1.50 keV	2.77 keV
Photon flux ($h\nu = \varepsilon_c$) I=100 mA; BW=0.1%	3×10^{12} photons/s, mrad	1.5×10^{13} photons/s, mrad
Monochromators	channel-cut	channel-cut
Crystals	Si(111) Si(220)	Si(111) Si(220) Ge(220)
Resolution $\Delta E/E$	Si(111)-$(1\text{-}4) \times 10^{-4}$ Si(220)-$(1\text{-}3) \times 10^{-4}$	Si(111)-$(1\text{-}15) \times 10^{-4}$ Si(220)-$(1\text{-}3) \times 10^{-4}$
Detectors	Ion chambers (Argon)	Ion chambers (Kripton)

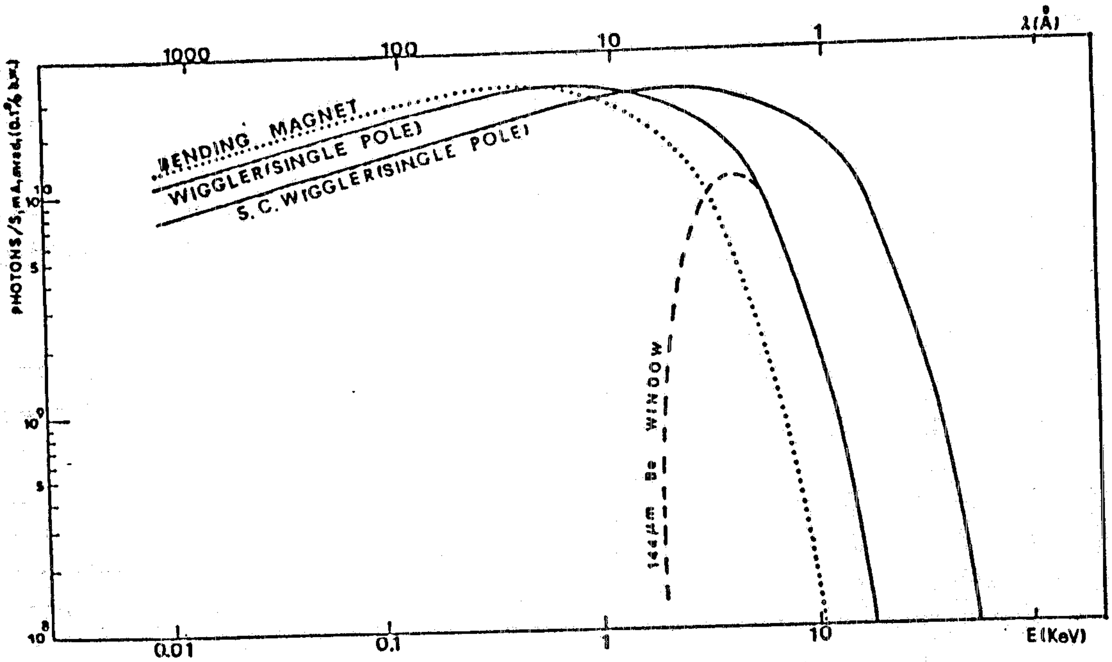

Fig. 4 - SR spectrum from various sources.

A perspective view of the experimental stations downstream the bending magnet line is shown in Fig. 5. The radiation emitted from 10 mrad of the electron orbit is subdivided among 5 monochromators through a system of deflecting mirrors. The low-energy part of the spectrum ($\lesssim$ 150 eV) is deflected towards the upper floor laboratory, which is equipped with a Jobin-Yvon and

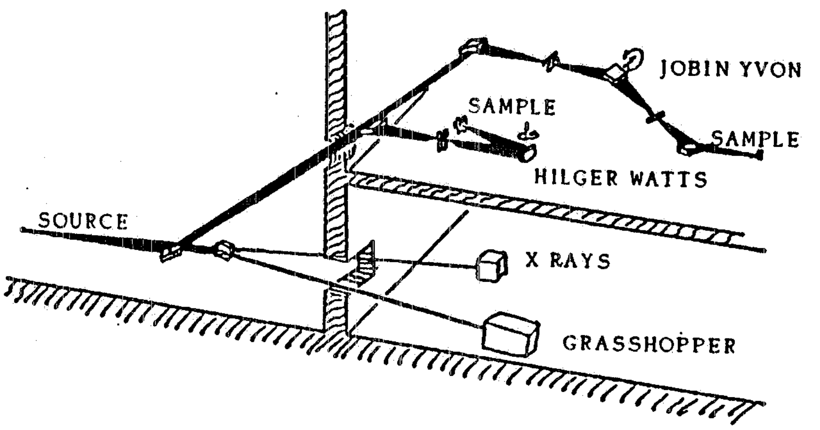

Fig. 5 - A general view of the PULS facility.

a Hilger-Watts monochromator. Their spectral ranges are from 10 to 100 eV and from 5 to 50 eV respectively. The actual experimental techniques are angle-resolved and angle-integrated photoemission for the Jobin-Yvon monochromator and reflectance/luminescence lifetime for the Hilger-Watts. On the ground floor 2 experimental stations are located. The X-rays beam line whose monochromator was entirely built at Frascati, is mainly devoted to EXAFS and SAXS experiments.

The Grasshoppers monochromator, which covers the spectral range 50-800 eV, is used mainly for angle resolved/integrated photoemission. Further details are given in ref.(5).

Plans for the future

Several improvements are being carried out on the machine by the ADONE scientific and technical staff.

We have already mentioned the e^+e^- physics programme, which will require the upgrade of the injection system, from the new gun for the Linac to the new septum magnet for positron injection in ADONE. The realignement of the entire ring is foreseen for the next shutdown (Spring 1986) together with substantial improvements to the vacuum system. Also a new feedback system to cure both longitudinal and transverse instabilities, and new beam position monitors are in progress.

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